PHYSICAL REVIEW VOLUME 89, NUMBER 4 FEBRUARY 15, 1953

Levels of Al^{25} from the $Mg^{24}(d,n)Al^{25}$ Reaction*

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(Received October 27, 1952)

A 67-kev target of Mg^{24} was bombarded with 4.007-Mev deuterons, and the neutron groups from the $Mg^{24}(d,n)Al^{25}$ reaction were studied at seven different angles with Ilford C2 emulsions. The observed Q values are $+0.07\pm0.06$, -0.38 ± 0.06, -0.88 ± 0.05, -1.74 ± 0.04, (-1.87 ± 0.04), -2.44 ± 0.04, -2.67 ± 0.04, (-2.85 ± 0.04), and -3.04 ± 0.03 Mev. The neutron groups with the Q values -2.44, -2.67, and -3.04 Mev correspond to virtual states of Al^{25} which have previously been seen as $Mg^{24}+p$ resonances. From the Butler theory for the angular distribution of the stripped neutrons, the ground state of Al^{25} is described by $J=3/2$ or $5/2$, even parity; the first excited state is $J=1/2$, even parity, and the second excited state is likely to be $J=3/2$ or $5/2$, even parity. The level structure of Al^{25} is compared to that of Mg^{25}.

I. INTRODUCTION

A KNOWLEDGE of the energy level structure of light nuclei which includes parity and total angular momentum values of the individual levels as well as their excitation energies is valuable for testing theories concerned with nuclear structure and the nature of nuclear forces. The low-lying levels of mirror nuclei, for example, may be compared to judge the validity of the charge symmetry hypothesis. Theories which predict the quantum numbers of the levels may be tested directly.

The recent work of Butler[1] which has stimulated experimental and theoretical interest in (d,p) and (d,n) reactions provides a method for determining the parity and, to a degree, the angular momentum of the levels of the residual nuclei from these reactions. A reduction of ambiguity in level assignments may be achieved in the study of these reactions by choosing a target nucleus of zero spin.

The study of Al^{25} by way of the $Mg^{24}(d,n)Al^{25}$ reaction is of particular interest, since the mirror nucleus Mg^{25} has been subjected to some rather thorough spectral analyses. The nucleus Al^{25} has recently been investigated[2] by the elastic scattering of protons from Mg^{24}, and a phase shift analysis of the data has made possible the assignments of several of the higher levels.[3] The $Mg^{24}(d,n)Al^{25}$ reaction would yield information on the bound levels of Al^{25}, and any levels in the overlapping region could serve as checks on the classification arguments.

An incidental bit of information from the $Mg^{24}(d,n)Al^{25}$ reaction is the ground-state Q value which would provide an independent value for the mass of Al^{25}. This value of 24.998306 ± 0.000099 amu may be compared to the value of 24.99817 amu derived from the $Al^{25}(\beta^+)Mg^{25}$ end-point energy of 3.1 Mev.[4,5]

II. EXPERIMENTAL PROCEDURE

Deuterons having an energy of 4.007 Mev were allowed to fall on a thin Mg^{24} target. The outgoing neutrons were detected at various angles with 200-micron Ilford C2 emulsions positioned in air 10 cm from

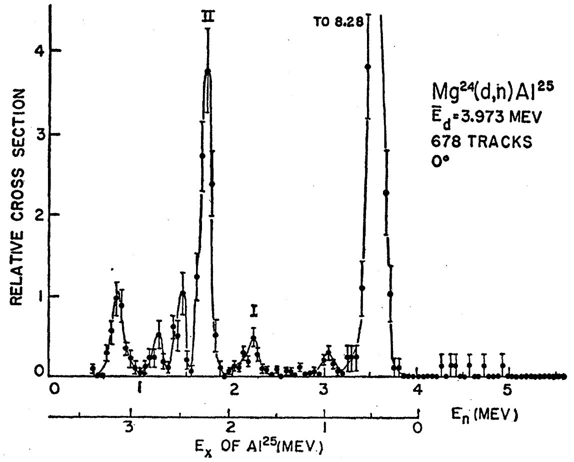

FIG. 1. Neutron energy spectrum at 0° to the incident deuteron beam. The $O^{16}(d,n)F^{17}$ groups are identified by I and II.

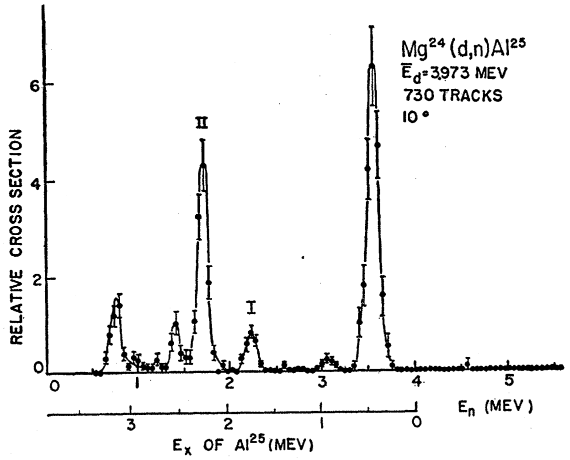

FIG. 2. Neutron energy spectrum at 10° to the incident beam.

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* Work supported by the Wisconsin Alumni Research Foundation and the U. S. Atomic Energy Commission.

† Atomic Energy Commission Predoctoral Fellow.

[1] S. T. Butler, Proc. Roy. Soc. (London) **208**, 559 (1951).

[2] Mooring, Koester, Goldberg, Saxon, and Kaufmann, Phys. Rev. **84**, 703 (1951).

[3] L. J. Koester, Jr., Phys. Rev. **85**, 643 (1952).

[4] Atomic masses of Mg^{24} and Mg^{25} taken from the table of C. W. Li, Phys. Rev. **88**, 1038 (1952).

[5] D. Van Patter (private communication).

the target. The plates were exposed for 1.28 microampere-hours. The laboratory angles of observation were 0°, 10°, 30°, 40°, 60°, and 150°. A total of 5736 acceptable tracks were measured according to standards adopted earlier.[6]

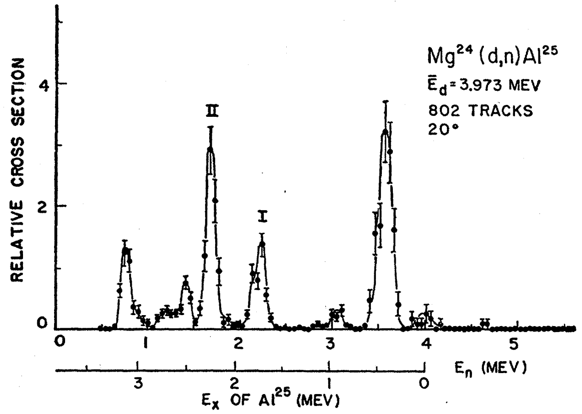

FIG. 3. Neutron energy spectrum at 20° to the incident beam.

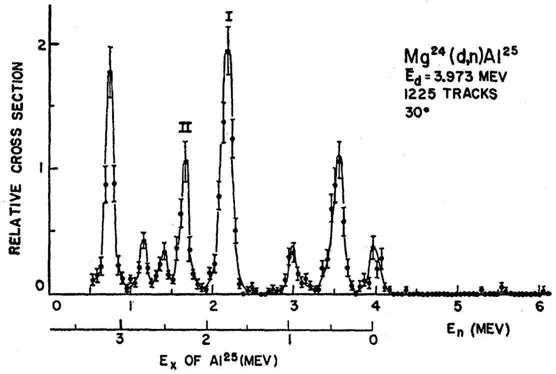

FIG. 4. Neutron energy spectrum at 30° to the incident beam.

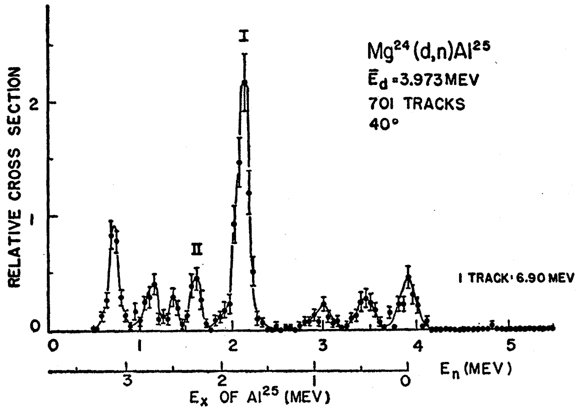

FIG. 5. Neutron energy spectrum at 40° to the incident beam.

The target was prepared by heating $Mg^{24}O$ on a tantalum strip in vacuum, slowly raising the temperature of the strip until a metallic deposit was seen on a glass plate placed beyond the target backing.[7,8] Ten successive evaporations were necessary to deposit a satisfactory layer (i.e., 45 kev for 4.0-Mev deuterons) on a ten mil tantalum backing positioned two inches from the oxide. The thickness was determined by measuring the increase in mass of the target backing. The target was set at an angle to increase its thickness to 67 kev. Oxygen in the target, identified by neutrons from the $O^{16}(d,n)F^{17}$ reaction, may have arisen from the brief exposures to air when the target was being prepared, or may indicate some direct evaporation of the MgO. The oxygen content was, however, less than one-third that of MgO, indicating that the tantalum does partially reduce the oxide.[9]

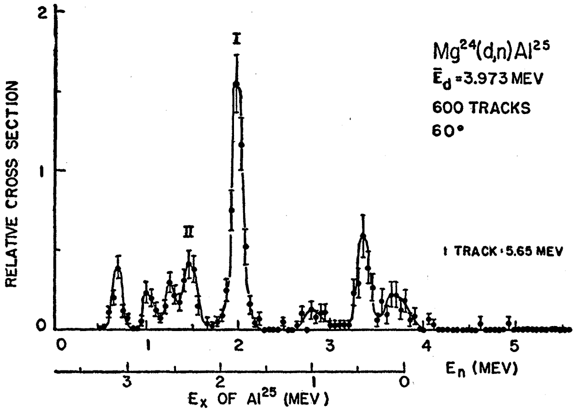

FIG. 6. Neutron energy spectrum at 60° to the incident beam.

III. EXPERIMENTAL RESULTS

A. Neutron Spectra

The neutron spectra from the $Mg^{24}(d,n)Al^{25}$ reaction are shown in Figs. 1 to 7. The two neutron groups

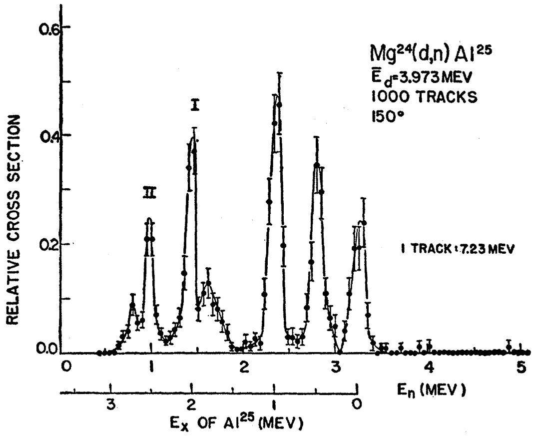

FIG. 7. Neutron energy spectrum at 150° to the incident beam.

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[6] Johnson, Laubenstein, and Richards, Phys. Rev. **77**, 413 (1950).

[7] Mg^{24} isotope supplied by the Y-12 Plant, Carbide and Carbon Chemicals Division, Union Carbide and Carbon Corporation, Oak Ridge, Tennessee.

[8] The author would like to thank Dr. J. N. Cooper for informing him of this technique. Revs. Sci. Instr. **23**, 764 (1952).

[9] The comparison with MgO targets is based on some unpublished neutron spectra measurements made by the author.

TABLE I. Q values from the $Mg^{24}(d,n)Al^{25}$ reaction and excitation energies of Al^{25} (Mev.)

Laboratory angle of observation 0°	10°	20°	30°	40°	60°	150°	Weighted average Q value	Other Q values	Best excitation energy	Total No. of tracks
···	···	+0.09	+0.10	+0.07	+0.02	+0.08	+0.07±0.06		0	267
−0.38	−0.37	−0.34	−0.34	−0.38	−0.38	−0.40	−0.38±0.06		0.45±0.03	1100
−0.88	−0.86	−0.85	−0.86	−0.88	−0.82	−0.89	−0.88±0.05		0.95±0.03	430
−1.78	···	−1.76	···	···	···	−1.73	−1.74±0.04		1.81±0.04	103
(−1.87)	(−1.86)	(−1.90)	···	···	···	···	−1.87±0.04		1.94(?)	14
−2.43	−2.46	−2.44	−2.43	−2.45	−2.48	−2.43	−2.44±0.04	−2.439[a]	2.51±0.05	372
−2.66	−2.65	−2.64	−2.67	−2.67	−2.71	···	−2.67±0.04	−2.626[a]	2.70±0.05	302
···	(−2.87)	···	(−2.82)	(−2.84)	···	···	−2.85±0.04		2.92(?)	35
−3.06	−3.05	−3.05	−3.05	−3.03	−3.03	···	−3.04±0.03	−3.018[b]	3.09±0.06	750

[a] This value was computed from values of capture gamma-ray resonance energies (see reference 16) and the binding energy of the deuteron [R. Mobley and R. Laubenstein, Phys. Rev. **80**, 309 (1950)].

[b] See reference 2 and Mobley and Laubenstein, reference a.

labeled I and II occur at the correct energies and with the correct angular distributions[10] to be attributed to $O^{16}(d,n)F^{17}$ reaction. Group I corresponds to the formation of F^{17} in the ground state, and group II corresponds to the first excited state. The observed ranges of group I were paired with the computed energies of this group[11] to check the calibration of these plates. The points were seen to agree with Rotblat's table for Ilford C2 emulsions,[12] although the latter was meant to apply to emulsions exposed in vacuum. The table was used with no correction made for exposure in air. The correction was expected to be of the order of two percent.[13]

The data have been corrected for variation of the n-p cross section with energy[14] and for variation of the probability that the tracks leave the emulsion.[15] To improve the statistics of weak groups, additional plate area was scanned and measurements made for certain energy intervals. It was necessary to normalize according to the area of the particular plate scanned. This normalization was also applied to all the plates to facilitate comparison of the group intensities at different angles.

Figure 1 illustrates the data at 0°. All groups other than those arising from the $O^{16}(d,n)F^{17}$ reaction are attributed to the $Mg^{24}(d,n)Al^{25}$ reaction by noting the energy variation of the groups with angle of observation. There was no evidence of carbon contamination of the target at this angle or at the other angles. The group of lowest neutron energy corresponds to a level of Al^{25} seen[2] through the elastic scattering of protons from Mg^{24}. This level will be discussed later when the interpretation of the angular distributions is considered. The groups at 1.2 and 1.4-Mev neutron energies are identified as those corresponding to levels of Al^{25} which were inferred from the study of the $Mg^{24}(p,\gamma)Al^{24}$ reaction.[16]

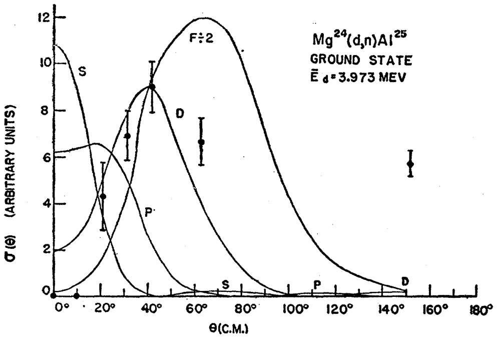

FIG. 8. Angular distribution of neutrons from the $Mg^{24}(d,n)Al^{25}$ reaction, with the Al^{25} in the ground state.

Background plates exposed at this angle do not account for the six tracks which have neutron energies in excess of 4.2 Mev. The data at other angles give no evidence for a level of Al^{25} which would account for all of these tracks. A few near 4.0 Mev might be associated with the ground-state group that begins to appear at 20°, while the tracks of higher energies might possibly be attributed to the $Mg^{25}(d,n)Al^{26}$ or $Mg^{26}(d,n)Al^{27}$ reactions which are highly exoergic. The Mg^{25} impurity is assayed to be 0.301 percent, Mg^{26} is 0.114 percent, and Mg^{24} is 99.59 percent.[7]

Figures 2 to 7 illustrate the remaining data. At 150° (Fig. 7), the first three levels of Al^{25} are clearly defined, and one neutron group which was not resolved at the other angles is now visible at the right of group I. This

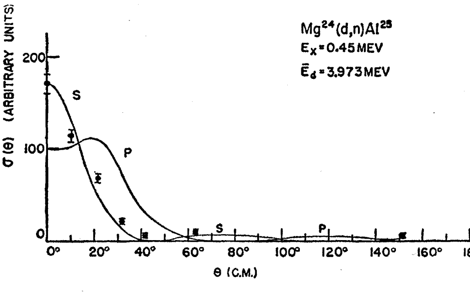

FIG. 9. Angular distribution of neutrons from the $Mg^{24}(d,n)Al^{25}$ reaction, with the excitation energy of 0.45 Mev for Al^{25}.

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[10] F. Ajzenberg, Phys. Rev. **83**, 693 (1951).

[11] T. W. Bonner and J. W. Butler, Phys. Rev. **83**, 1091 (1951).

[12] J. Rotblat, Nature **167**, 550 (1951); **165**, 387 (1950).

[13] A. J. Dyer, Australian J. Sci. Research **A5**, 104 (1952).

[14] R. K. Adair, Revs. Modern Phys. **22**, 249 (1950).

[15] H. T. Richards, Phys. Rev. **59**, 796 (1941).

[16] Grotdal, Lönsjö, Tangen, and Bergström, Phys. Rev. **77**, 296 (1950).

group is associated with the marked asymmetry of group I at 0° and 20°. The more rapid variation of the neutron energy with angle for the $O^{16}(d,n)F^{17}$ neutrons permits resolution of these two groups at large angles. A level of Al^{25} at an excitation energy of 1.81 Mev may be inferred from this group. At a few angles, there is a suggestion of neutron groups which would be associated with levels at 1.94 and 2.92 Mev (see Table I). The intensities of these groups are such that it is possible, but unlikely, that they arise from the Mg^{25} or Mg^{26} impurities.

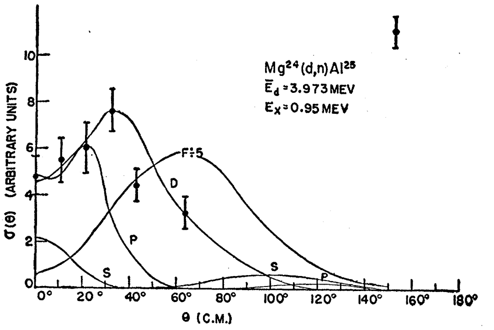

FIG. 10. Angular distribution of neutrons which correspond to the 0.95-Mev level of Al^{25}.

Table I lists the Q values of the $Mg^{24}(d,n)Al^{25}$ reaction for the various neutron groups. The average Q value for each group is computed after weighting each value according to the number of tracks in the group at that angle. The cited uncertainties of the Q values represent not only the variation of the calculated Q values among the plates which is ±20 kev in most cases but also the uncertainty in the range energy relation and geometric uncertainties. The latter includes orientation of the target, finite target size, and width of region of emulsion scanned; these should contribute not more than ±10 kev. The beam energy uncertainty is less than ±5 kev. For 4.0-Mev neutrons, the range-energy relation contributes ±40 kev, this being reduced for lower energy neutrons. However, the excitation energies of Al^{25} close to the ground state are known with greater certainty because the uncertainty of the range-energy relation tends to cancel out.

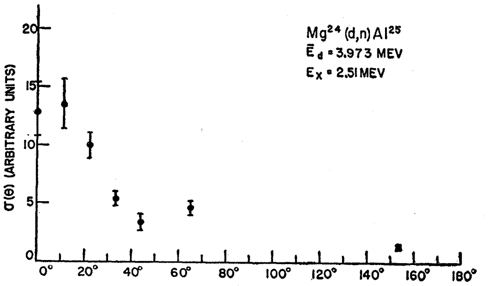

FIG. 11. Angular distribution of neutrons which correspond to the 2.51-Mev level of Al^{25}.

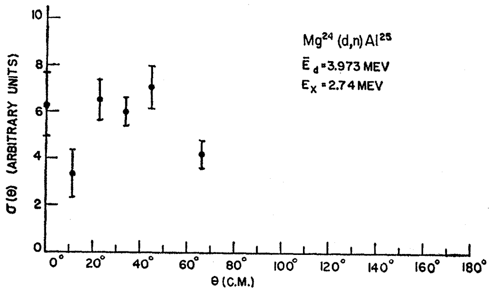

FIG. 12. Angular distributions of neutrons which correspond to the 2.74-Mev level of Al^{25}.

It is possible to calculate the absolute differential cross sections if the density of hydrogen atoms in the emulsion and the number of target nuclei per square centimeter are known along with the total charge collected by the target. The cross section for the neutron group at 10° corresponding to the first excited state of Al^{25} (i.e., $E_x=0.45$ Mev) was computed to be $(4\pm2)\times10^{-26}$ cm² per steradian. This yields a factor of 0.7 $\times10^{-26}$ cm² per steradian per ordinate unit on the first seven figures.

B. Angular Distributions

The availability of the data at the seven angles permits an examination of the angular distributions of several neutron groups. They are given in Figs. 8 to 13, and are identified by the corresponding excitation energies of Al^{25} as derived from this experiment. The points were computed on the basis of the number of tracks in the particular group, rather than the height of that group as it appeared in foregoing figures. The angles of observation and intensities have been converted to the center-of-mass system.[17]

IV. INTERPRETATION OF THE ANGULAR DISTRIBUTIONS

According to Butler's theory,[1] the angular distribution of the neutrons from a particular reaction will depend very markedly on the orbital angular momentum l_p attributed to the proton before capture. If zero spin and even parity are assumed for the ground

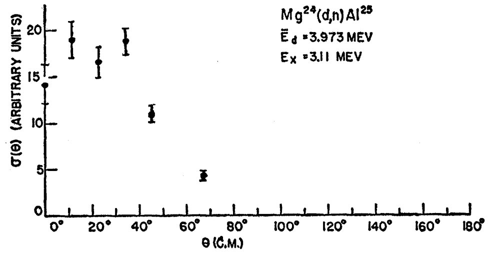

FIG. 13. Angular distribution of the neutrons from the $Mg^{24}(d,n)Al^{25}$ reaction with Al^{25} excitation energy of 3.11 Mev.

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[17] M. Moskow, Master's Essay, The Johns Hopkins University (1948) (unpublished).

TABLE II. Behavior of the nuclear factor N.

E_x(Mev)	l_p	$\frac{C_1\sigma(\theta)_{\text{calc}}}{N}$	$C_2\sigma(\theta)_{\text{exp}}$	$\frac{NC_2\sigma(\theta)_{\text{exp}}}{C_1\sigma(\theta)_{\text{calc}}}$
0.00	2	1.00	1.00	1.00
0.45	0	0.68	19.1±0.4	28.1
0.95	2	1.86	0.86±0.21	0.46

state of Mg^{24}, the total angular momentum of the residual nucleus Al^{25} will be $J=l_p\pm\frac{1}{2}$. The parity of this state will be even if l_p is even and odd if l_p is odd. The ambiguity for J is removed in the case $l_p=0$, where $J=\frac{1}{2}$. Butler's expression [i.e., Eq. (34)][1] when applied to this reaction is explicit in so far as the angular distribution is concerned except for the choice of the nuclear radius. The equation $r_0=1.49\ (A^{\frac{1}{3}}+1)\times10^{-13}$ cm yields a value 5.80×10^{-13} cm. The solid lines which appear in Figs. 8 to 10 have been computed from Butler's expression employing this nuclear radius. No correction was made for the Coulomb effect.

The comparison of experimental points to the theoretical curves in Fig. 8 would prompt an assignment of $J=3/2$ or $5/2$, even parity, to the ground state of Al^{25}. As in Figs. 9 and 10, the curve which best fits the data has been drawn to the appropriate scale while the companion curves have magnitudes in relation to the chosen curve designated according to the Butler expression, neglecting the nuclear factor N and the statistical factor $(2J+1)$. This assignment is consistent with the known spin assignment[18] of $J=5/2$ for the ground state of Mg^{25}, the mirror nucleus of Al^{25}. It is also in agreement with the prediction of the Mayer spin-orbit model[19] which requires $J=5/2$, even parity. Deviations of the points from the curves at larger angles may be attributed to compound nucleus formation which is expected to be noticeable because of the small differential cross sections for this state. The angular distribution associated with the first excited state of Al^{25} is shown in Fig. 9. The data clearly show the level to be $J=\frac{1}{2}$, even parity, because the forward maximum implies the capture of a proton by Mg^{24} with $l_p=0$. The cross section is quite small at $\theta_{\text{lab}}=150°$ compared to values in the forward direction. The data for the second excited state (i.e., $E_x=0.95$ Mev) would suggest $J=3/2$ or $5/2$, even parity, but there is a slight possibility that the designation is $J=\frac{1}{2}$ or $\frac{3}{2}$, odd parity, for this level. The experimental cross-section value at $\theta_{\text{lab}}=150°$ is very large compared to values in the forward direction and deviates markedly from the P and D (i.e., $l_p=1$ and $l_p=2$, respectively) curves. The values of the absolute differential cross sections are rather small for this reaction.

It should be emphasized that since Butler's analysis treated only bound levels of the residual nucleus, there is no justification in applying it to states unstable against emission of the captured particle. Also the singularity of Butler's expression for $k_p=0$ (k_p being the wave number of the captured particle) is not experimentally realized. This observation further suggests a failing of the theory in this region. Consequently, the three remaining angular distributions were not compared to the theoretical curves. A more recent extension of this theory by Friedman and Tobacman[20] considers the virtual states as well as the bound states. The expression for the angular distributions for bound states is found to be similar to that of Butler and lacks the singularity. The expression for virtual states has additional incoherent terms, and a quantity df/dE which depends on the behavior of the wave function at the nuclear surface. The partial widths for particle and gamma-emission also enter. These quantities are not explicitly known. The Born approximation has been employed by Bhatia, Huang, Huby, and Newns[21] to calculate the angular distributions of (d,p) and (d,n) reactions. The results agree with Butler's where the latter theory is applicable and do not exhibit singularities at $k_p=0$.[22] The expression, however, does possess more parameters than Butler's expression.

A possible check on these theories may be afforded by consideration of the data of Fig. 13 since the level to which the data applies has already been assigned $J=\frac{3}{2}$, odd parity from the partial wave analysis of the elastic scattering data.[3] The neutron distribution is noted to have a slight minimum in the forward direction and drops rapidly beyond $\theta(\text{c.m.})=34°$. If reasonable assumptions are made regarding df/dE in Friedman and Tobacman's expression, and gamma-emission is assumed to be negligible, the theoretical curve for $l_p=1$ has a forward maximum, decreasing monotonically to one-half the peak value at 60°. The prediction of Bhatia and Huang is that of a forward maximum which drops steadily to one-fifth the maximum value at 60°. Neither of these curves fits the data well enough to suggest the

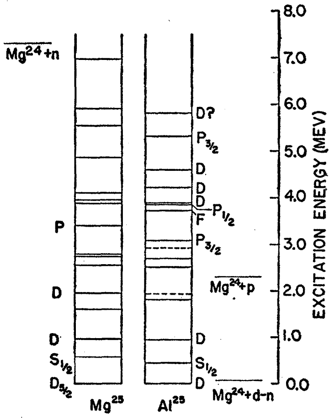

FIG. 14. Energy levels diagrams of Al^{25} and Mg^{25}.

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[18] J. E. Mack, Revs. Modern Phys. 22, 64 (1950).

[19] M. G. Mayer, Phys. Rev. 78, 16 (1950).

[20] F. L. Friedman and W. Tobacman (to be published).

[21] Bhatia, Huang, Huby, and Newns, Phil. Mag. 43, 485 (1952).

[22] The equivalence of the essential features of the Butler theory to the Born approximation calculation has been demonstrated by P. B. Daitch and J. B. French [Phys. Rev. 87, 900 (1952)]; and R. G. Thomas, private communication.

assignment of $l_p=1$. One is prompted to consider an extrapolation of the Butler curves from the range of validity and notes in contrast to the above treatments a preference for an $l_p=1$ assignments. If this procedure is tolerated, it is tempting to go a step further and hazard guesses for the levels at 2.51- and 2.74-Mev excitation energies. That at 2.51 Mev would appear to have an assignment of $l_p=0$ making it $J=\frac{1}{2}$, even parity, while the level at 2.74 Mev would be described with $l_p=1$ or 2. It may be noted in passing that while the level at 2.51-Mev excitation energy corresponds to the k_p close to zero, the absolute cross section of the $Mg^{24}(d,n)Al^{25}$ reaction for this level is not noticeably greater than the cross sections for the other levels.

Butler's expression for $\sigma(\theta)$ contains an angle independent coefficient N which is a function of the initial and final nuclei. It may be of interest to note the variation of this nuclear factor among the levels of Al^{25} which have been classified in the experiment. The levels are assumed to be $J=5/2$, even parity, for the ground state, $J=\frac{1}{2}$, even parity, for the first excited state, and $J=\frac{3}{2}$, even parity, for the second excited state. The experimental and theoretical values are compared at the peaks of the angular distributions which are 40°, 0°, and 35°, respectively. The theoretical values are not sensitive to the choice of J (i.e., either 3/2 or 5/2) which enters in by way of the statistical factor $(2J+1)$. The comparison is shown in Table II. The third and fourth columns are normalized to unity for the ground-state entry. The last column is the ratio of these values.

It is clear from this comparison that the nuclear factor for the two levels with $l_p=2$ varies by only a factor of two, but the nuclear factor is more than an order of magnitude larger for the level involved in the S wave proton capture. A similar analysis of the $Be^9(d,n)B^{10}$ reaction[23] for which the first five states of B^{10} are described by the designation $l_p=1$ yields a result that this nuclear factor has a variation of only a factor of three among these levels. All these observations suggest a strong dependence of the nuclear factor on l_p.

V. ENERGY LEVELS OF THE MIRROR NUCLEI Al^{25} AND Mg^{25}

A description of the level structure of Al^{25} from its ground state to 6.1 Mev can now be given, for the region from 2.7 to 6.1 Mev has been investigated by the elastic scattering of protons.[2,3] The data of the present experiment overlap the above mentioned region with the 3.11-Mev level in common, and confirm the two levels reported from the study of the $Mg^{24}(p,\gamma)Al^{25}$ reaction.[16] The structure of Mg^{25} is also presented in Fig. 14 for the purpose of comparison. This latter diagram is a compilation of levels seen from the $Al^{27}(d,\alpha)Mg^{25}$ and $Mg^{24}(d,p)Mg^{25}$ reactions.[24,25] The assignments are those of Holt, deduced from a study of the angular distributions of the proton groups from the $Mg^{24}(d,p)Mg^{25}$ reaction.[26] The designations of the upper levels of Al^{25} were made from a partial wave analysis of the $Mg^{24}(p,p)$-Mg^{24} data,[3] while those for the lowest three levels are derived from the data of this experiment. The symbols are not meant to imply any particular nuclear model. The value for the total angular momentum of the state, as has been stated, it $J=l_p\pm\frac{1}{2}$ except when $l_p=0$ in which case $J=\frac{1}{2}$. The parity is even if l_p is even and odd if l_p is odd, for the ground state of Mg^{24} is assumed to have zero spin and even parity. The two dashed lines on the diagram for Al^{25} indicate the doubtful levels previously mentioned. Because nuclear emulsions cannot resolve levels with a spacing smaller than 100 kev, it is possible that doublets are present and undetected in the region of Al^{25} below 3.0-Mev excitation energy. This remark also applies to the region of Mg^{25} above 4.0-Mev excitation energy.

TABLE III. Cross sections of the $Mg^{24}(d,n)Al^{25}$ and $Mg^{24}(d,p)Mg^{25}$ reactions.

$Mg^{24}(d,n)Al^{25}$		$Mg^{24}(d,p)Mg^{25}$	
E_x(Mev)	$\sigma(\theta)$ (cm²/sterad.)	E_x(Mev)	$\sigma(\theta)$ (cm²/sterad.)
0.00	$3.0\cdot10^{-27}$	0.000	$1.7\cdot10^{-26}$
0.45	$5.7\cdot10^{-26}$	0.583	$2.3\cdot10^{-25}$
0.95	$2.5\cdot10^{-27}$	0.976	$9.3\cdot10^{-27}$

The absolute cross section of the $Mg^{24}(d,n)Al^{25}$ and $Mg^{24}(d,p)Mg^{25}$ reactions for the three lowest states are compared in Table III. The values given are the differential cross sections at the peaks of the angular distributions. It is seen from the level diagrams that the l_p assignments agree. The values from the (d,p) reaction are from four to six times larger than the corresponding values from the (d,n) reaction. This is reasonable, for the (d,p) reaction is expected to have a larger cross section than the (d,n) reaction because of the Coulomb effect.[27] Since the $Mg^{24}(d,p)Mg^{25}$ reaction was studied with 8.0-Mev deuterons while 4.0-Mev deuterons were employed for the $Mg^{24}(d,n)Al^{25}$ reaction, the expectation is even greater for a larger (d,p) than (d,n) cross section in this case. The levels of Al^{25} and Mg^{25} are seen, therefore, to correspond very nicely below 1.0-Mev excitation energy. An unambiguous correspondence of levels above 1.0 Mev cannot be made at this time. However, one can see that the level densities of the regions to 6.0 Mev are approximately equal.

The author would like to express his gratitude to Professor H. T. Richards for many helpful and stimulating discussions, and to Dr. F. Ajzenberg for advice on the techniques of nuclear emulsions. The assistance of Mr. R. E. Benenson, Dr. J. R. Cameron, and Dr. Ajzenberg in the operation of the electrostatic generator is gratefully acknowledged.

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